TRANSFORMATIVE IMPACTS OF AI AND THE IOT ON HEALTHCARE DELIVERY: METHODOLOGIES, ETHICAL CONSIDERATIONS, AND ENHANCEMENT AVENUES

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Abstract:

The healthcare field is undergoing an enormous transformation mainly a result of the integration of artificial intelligence (AI) and the Internet of Things (IoT). This study investigates AI's varied responsibilities, which include patient authorization, scheduling appointments, billing, revenue management, improving patient experience, monitoring bed availability, symptoms triage, and enabling online consultations. AI makes significant improvements to personalized medical care by assisting with the development of individualized treatment plans depending on individual genetic profiles, resulting in improved patient care. Additionally, IoT connects a diverse set of devices, promoting continuous data sharing, efficient operation, and enhanced patient care. However, the extensive use of AI and IoT in healthcare creates serious ethical and privacy concerns, especially over confidentiality and Integrity. The study highlights the importance of a balanced approach that optimizes the advantages of technological advances while protecting patient rights. Furthermore, it explores global trends in healthcare IoT, emphasizing how these breakthroughs are creating substantial changes in the industry. As AI and IoT grow, they could spark additional transformations in healthcare, bringing both potential and challenges. This study explores at the methodology underlying these technologies, the ethical issues they raise, and the potential they have for improving healthcare accessibility and patient outcomes.

1 Introduction

The healthcare sector is undergoing a major revolution, driven by the integration of AI and the IoT. These technologies, combined with smart devices, are transforming the healthcare industry and administration, with advanced technology becoming crucial allies for medical professionals. According to an Accenture survey, 73% of global executives in healthcare have incorporated AI into different operational aspects of their industries, demonstrating the growing significance of AI in the healthcare sector [1]. By 2022, it's anticipated that AI-powered tools—like radiology's image analysis systems—will help analyze medical images in as many as 50% of all clinical incidents. Furthermore, it is projected that shortly, AI-enabled virtual health assistants will handle up to 20% of patient contacts, highlighting AI's growing impact on medical services. Furthermore, significant growth is anticipated in the worldwide healthcare IoT industry, which is expected to generate US$108.60 billion in sales by 2024. As a result, the market is expected to reach a volume of US$167.70 billion by 2028, representing a compound yearly rate of growth (CAGR) of 11.47% from 2024 to 2028. The US is expected to dominate this market, with US$9,377.00 million in projected revenue in 2024, highlighting its

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prominent position in the global Healthcare IoT ecosystem [2]. According to a JAMA study, AI systems performed equally well or better in diagnosing than human experts in about 90% of the scenarios. Still, as of 2020, just 2% of medical organizations worldwide were integrating AI into clinical operations [3]. AI-powered diagnostic systems have demonstrated a notable 40% decrease in treatment variation and 30% improvement in diagnostic precision, which has enhanced patient results and decreased expenses.

The WHO report [4] highlights the global disparity in modern medical technologies by stating that just 15% of healthcare providers in countries with low incomes have access to basic imaging equipment for diagnosis. This highlights an enormous disparity in the infrastructure of healthcare. IoT devices play a key role in this growth by enabling continuous monitoring of health as well as data gathering, which are vital to AI-driven healthcare applications. These devices range from wearable fitness trackers to intelligent medical monitoring devices. In the field of computing, AI focuses on imitating human cognitive processes, including decision-making and problem-solving. AI is applied in the healthcare industry using modern technologies including computer vision, machine learning, and natural language processing. Machine learning (ML) algorithms can now quickly scan through large data, spot complex trends, and reach well-informed conclusions because of these technologies. In order to improve accuracy and patient outcomes, AI systems can help doctors with complex surgeries or closely examine medical imaging for irregularities [5]. The IoT is a network of sensors and devices that are connected to communicate information. IoT devices in the healthcare industry, from advanced medical equipment to wearable fitness trackers, produce constant volumes of data. Innovative uses of this data include tracking vital signs in real-time, optimizing healthcare service, and enabling remote patient monitoring [6].

The integration of AI and IoT is transforming healthcare by performing tasks automatically, enhancing decision-making, and boosting patient outcomes [7]. AI algorithms utilize patient data from IoT devices to detect early disease indications and predict medical consequences. This enables preventative actions, which reduce issues and improve the quality of healthcare [8], [9]. Nevertheless, there are concerns regarding privacy and ethics with the use of AI and IoT in healthcare. Ensuring patient data protection, addressing potential algorithmic biases, and ensuring openness in AI-driven decision-making are critical [10], [11]. The development of precision health care, which customizes treatment for each patient according to their biological composition, way of life, and medical histories, further demonstrates how AI has the power to transform healthcare by enhancing treatment results and boosting scientific understanding. Intelligent algorithms (IAs) are revolutionizing healthcare by integrating with the widespread use of smart devices and IoT technology[12], [13]. These devices, which range from wearables to implanted sensors, create enormous amounts of data that IAs can use to gain meaningful insights. For example, smartwatches and fitness trackers give continuous health monitoring data, allowing for early diagnosis of anomalies and chronic disease treatment [14], [15]. Furthermore, IAs can improve the performance of smart medical equipment like insulin pumps and pacemakers by analyzing data in real-time and controlling them adaptively. Integrating IAs with smart devices allows healthcare practitioners to provide individualized and proactive treatment, which improves patient outcomes and reduces costs associated with healthcare [16], [17]. Furthermore, the use of intelligent agents to handle uncertainty in complex systems, such as using Monte Carlo simulations to assess power system reliability [18], has the potential to lead to novel approaches in healthcare, particularly in areas such as resource allocation and risk management. However, challenges such as data privacy, device compatibility, and algorithm dependability must be overcome in order to fully exploit the convergence's promise.

This study contributes to the field by:

- *Comprehensive AI & IoT analysis in healthcare:* Detailing AI's role in patient management, administration, and precision medicine.
- *IoT & AI integration:* Exploring the synergy between AI and IoT for improved healthcare delivery.
- *Ethical framework:* Addressing privacy and fairness concerns in AI and IoT implementation.
- *Global perspectives:* Analyzing global healthcare IoT trends to inform future research.
- *Methodology and impact on healthcare:* Investigating underlying technologies and demonstrating the potential for enhanced healthcare outcomes.

The remaining part of the article is structured as follows. Section 2 presents a literature review on advances in AI and IoT in healthcare, emphasizing extant research gaps. Section 3 describes the revolutionary effects of

AI and IoT on the healthcare industry. Section 4 discusses ethical and privacy considerations with applications of AI and IoT in healthcare. Section 5 delves into personalised medicine and worldwide trends in healthcare IoT. Section 6 concludes by summarizing major findings and future scope.

2 Literature review

In order to comprehensively assess the development of research accomplishments and identify existing research gaps, we conducted an extensive literature review focusing on the utilization of IoT and AI in the medical domain. Our analysis encompasses an in-depth analysis of the technological advancements, research findings, and challenges encountered within the AI and IoT realms in healthcare situations. The overview of our findings is concisely presented in Table 1, encapsulating the intricate landscape of AI and IoT integration in healthcare and shedding light on pertinent research insights and research gaps in the field of healthcare.

Table 1. Review of Literature on the application of evolving methodologies in healthcare.

Literature	Year	Technology	Findings	Challenges
[19]	2019	IoT, Big data analytics	- Smart devices, big data, IoT and AI analytics contribute to lower healthcare costs and higher patient satisfaction. - A revolutionary transformation in healthcare delivery is orchestrated by IoT-enabled big data execution platforms.	- Data privacy and security concerns associated with IoT devices and healthcare data. - Integration challenges in incorporating IoT technologies into existing healthcare systems.
[20]	2022	AI	- Introduction of AI tools into healthcare have led to substantial changes in patient care, healthcare administration, and wellness tracking. - AI technologies are utilized for data analytics, healthcare delivery, and addressing ethical issues.	- Integration of AI tools into existing healthcare workflows. -Ensuring ethical considerations and data privacy in AI-driven healthcare solutions.
[21]	2022	Intelligent healthcare systems	- Implementation of intelligent healthcare systems aim to mitigate healthcare challenges through safe data processing, remote patient monitoring, and tailored care.	- Data accuracy and reliability are paramount in the realm of intelligent healthcare systems. - Overcoming barriers to adoption and integration of intelligent healthcare technologies.
[22]	2022	IoT-based big data execution platforms	- IoT-based big data execution platforms optimize medical data administration and enable remote monitoring capabilities. - Revolutionize the delivery of healthcare services.	- Ensuring data accuracy and reliability in IoT-based big data platforms. -Scalability and interoperability challenges in deploying these platforms across diverse healthcare settings.
[23]	2022	Optimization techniques, EHR	- Utilizing Electronic Health Records (EHR) and optimization techniques prioritize patients for house calls, especially during the COVID-19 pandemic.	- Algorithm complexity and optimization challenges in implementing mathematical formulation-based approaches. - Data integration and interoperability issues with EHR systems.

[24]	2022	Blockchain, IoT, AI, Metaverse	- Integration of blockchain, IoT, and AI technologies in the Metaverse creates new opportunities in the healthcare industry. - Metaverse facilitates safe social and economic interaction, impacting healthcare.	- Ensuring data security and privacy in blockchain-enabled healthcare systems. - Overcoming technological barriers in integrating blockchain, IoT, and AI technologies in the Metaverse.
[25]	2022	Smart Sensors, AI, ML, DL, Edge computing, IoT	- Advancement of smart sensor technologies, AI, ML, DL, Edge Computing, and IoT is transforming connected healthcare. - Ensuring accountability and dependability in AI systems is crucial in IoT healthcare systems.	- Identifying variables affecting accountability and credibility to enhance system reliability and patient safety.
[26]	2023	Healthcare 5.0	- Healthcare 5.0 aims to offer fully autonomous medical services while considering the interdependencies across different medical conditions.	- Addressing challenges in achieving fully autonomous medical services. - Ensuring ethical and legal compliance in autonomous healthcare systems.
[27]	2023	Edge AI, IoT, Cloud computing	- Convergence of Edge AI, IoT, and cloud computing facilitates easier management of digital wellness in healthcare. - Demonstrates the interdisciplinary nature of healthcare informatics.	- Integration challenges associated with combining Edge AI, IoT, and cloud computing technologies. - Data security and privacy concerns in interconnected healthcare systems.
[28]	2023	Edge AI	- Edge AI models offer creative approaches to managing healthcare for various age groups. - Addressing upcoming prospects in digital healthcare systems.	- Technical complexities in implementing Edge AI solutions. - Ensuring interoperability and compatibility with existing healthcare infrastructure.

Overall, the integration of digital technologies in healthcare holds immense promise in navigating the labyrinth of contemporary healthcare challenges, unlocking the full potential of patient outcomes, and fine-tuning the intricate machinery of healthcare delivery processes, meticulous dedication to upholding data accuracy and reliability within intelligent healthcare systems stands as the cornerstone of innovation and progress. However, significant challenges such as data security, interoperability, and ethical considerations need to be carefully navigated to realize the full potential of these technologies in healthcare.

3 Healthcare operations with AI & IoT

3.1 Basic information

Today's healthcare system is not just about medical experts like physicians and surgeons using their hands to make decisions. The application of AI technology in the medical field is progressively advancing to include "robot intervention" services.

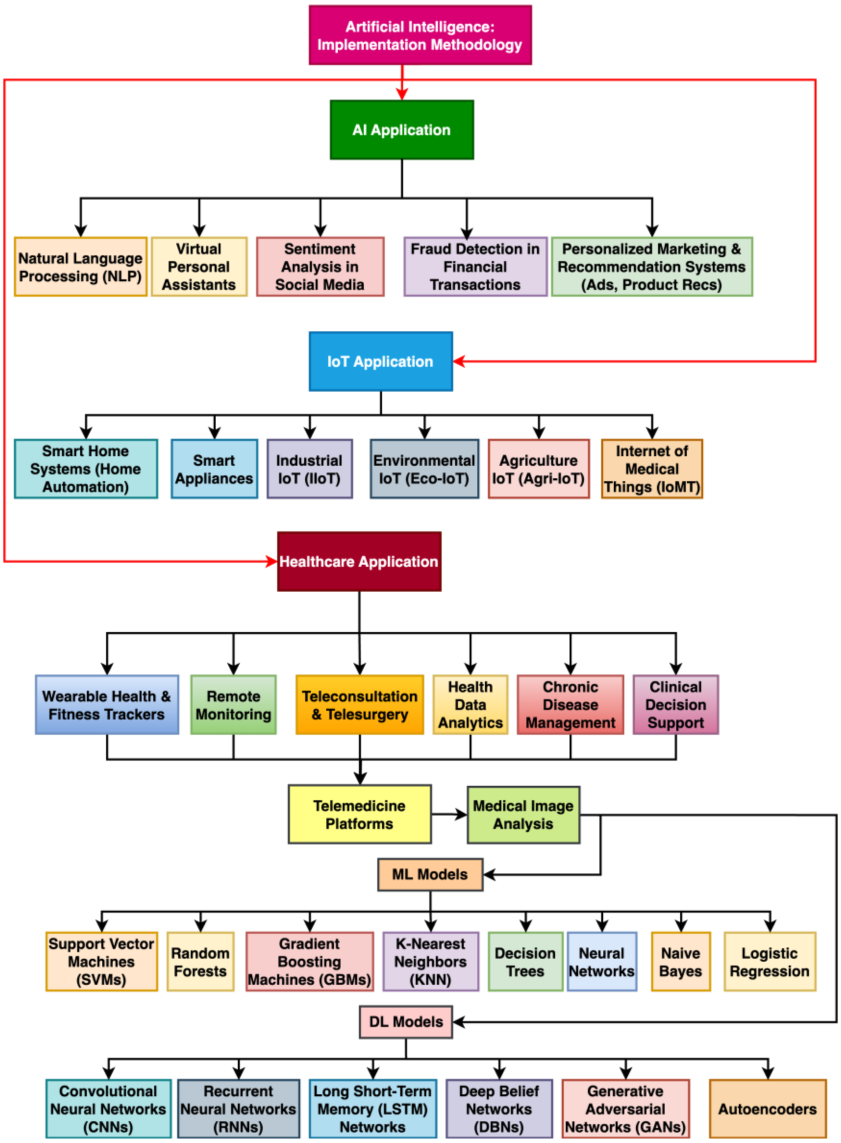

Figure 1. Block diagram depicting the transformative impacts of AI and IoT on healthcare delivery.

We are aware that trade between countries is set to shift because of artificial intelligence. Thanks to sophisticated automation, smart equipment, and effective analytical and processing capacity, AI is ready to support human intelligence and provide us with scalable and sustainable solutions, even in the healthcare sector [29]. Undoubtedly, AI is a novel form of general-purpose technology (GPT) that can assist human work and human skills like thinking, creativity, and multitasking. In a nutshell, AI is the extraction of knowledge from a range of technologies, such as machine learning, computer vision, audio processing, speech analytics, cognitive robots, and language processing. People's latent potential can be unlocked by AI, allowing individuals to make more meaningful contributions to society and deliver responses that are more timely, accurate, and relevant [29]. By using computer and gadget intelligence, AI boosts human conclusion. AI and IoT will influence the direction of healthcare in the future. Figure 1. depicts the transformative impacts of AI and the IoT on healthcare delivery, focusing on methodologies, ethical considerations, and enhancement avenues. It outlines the implementation methodology across three main areas: AI applications, IoT applications, and healthcare applications. Within the healthcare domain, various AI techniques are highlighted, including natural language processing (NLP), virtual personal assistants, sentiment analysis in social media, fraud detection in financial transactions, and personalized marketing & recommendation systems. Furthermore, the diagram illustrates a range of machine learning (ML), and deep learning (DL) models utilized in healthcare, such as convolutional neural networks (CNNs), recurrent neural networks (RNNs), long shortterm memory (LSTM) networks, and others. These models find application in diverse healthcare settings, including Smart Home Systems, Telemedicine Platforms, Medical Image Analysis, and more. Overall, the diagram showcases the multifaceted nature of AI implementation in healthcare, emphasizing its potential to revolutionize healthcare delivery through innovative methodologies and ethical considerations.

The healthcare sector is changing because of two very potent technologies: IoT and AI [30]. It is clear from this summary's conclusion that these developments are fundamentally altering healthcare. AI is like having a better personal assistant. It makes diagnosis more accurate and treatment plans more detailed, which helps medical professionals—including nurses—do their jobs more successfully. It is like having a very clever medical sidekick. Every kind of medical equipment, from complex hospital systems to cardiac video display displays, is secretly connected by the Internet of Things. This streamlines the sharing of statistics, improving treatment for afflicted individuals. However, we also need to consider the serious privacy and equity issues raised by the application of AI and IoT[5], [7]. Our analysis confirmed how AI benefits hospitals—from handling increasingly complicated sources to predicting the needs of those who may be impacted. It also alluded to the potential for personalized medicine, in which a patient's course of treatment is tailored to their genetic composition. We cannot, however, ignore the moral and privacy concerns. We need to use AI and IoT ethically to guarantee patient data security and equitable decision-making. Healthcare is evolving as a result of AI and IoT, which combine human expertise and contemporary technology. We are improving the care provided to affected persons, learning more about drugs, and making healthcare more environmentally friendly. This is a road we need to take carefully, always considering the patients' best interests. In addition to a breakthrough in medicine, combining AI and IoT offers a better and more egalitarian healthcare future for everybody. Figure 2 offers a visual representation of the multifaceted role of AI in healthcare, showcasing its diverse applications across the spectrum of medical domains.

3.2 AI's multidimensional role in healthcare

Patient Authentication: Patient authentication is a critical aspect of healthcare security, and AI technologies are increasingly being utilized to bolster authentication processes. By implementing threat-based authentication mechanisms, AI systems can analyze various factors associated with each login attempt to assess potential risks. For example, suspicious login patterns such as logging in from unusual IP addresses or at odd hours of the night can trigger alerts for further scrutiny. These AI-driven authentication systems not only enhance security but also ensure compliance with regulations such as the Health Insurance Portability and Accountability Act (HIPAA) [31].

Online Appointment: AI-powered appointment scheduling systems have revolutionized the way healthcare facilities manage appointments, leading to improvements in efficiency and patient satisfaction. By automating scheduling tasks, AI reduces the burden on administrative staff and minimizes errors, resulting in smoother appointment processes. Moreover, AI algorithms can analyze historical data to predict appointment demand and optimize scheduling to minimize wait times and maximize resource utilization. This not only benefits patients by offering convenient self-service options but also enables healthcare providers to deliver timely and effective care [32].

Billing and Revenue: Medical billing and revenue cycle management are complex processes that can be significantly enhanced through the application of AI. AI-powered medical billing software automates billing procedures, reducing errors and accelerating reimbursement cycles. Through the analysis of extensive billing data, AI algorithms wield the power to discern intricate patterns and trends, thereby optimizing revenue collection processes and enhancing decision-making capabilities. Additionally, AI-enabled billing systems can enhance compliance with regulatory requirements and ensure accurate documentation, leading to better financial outcomes for healthcare practices [33], [34].

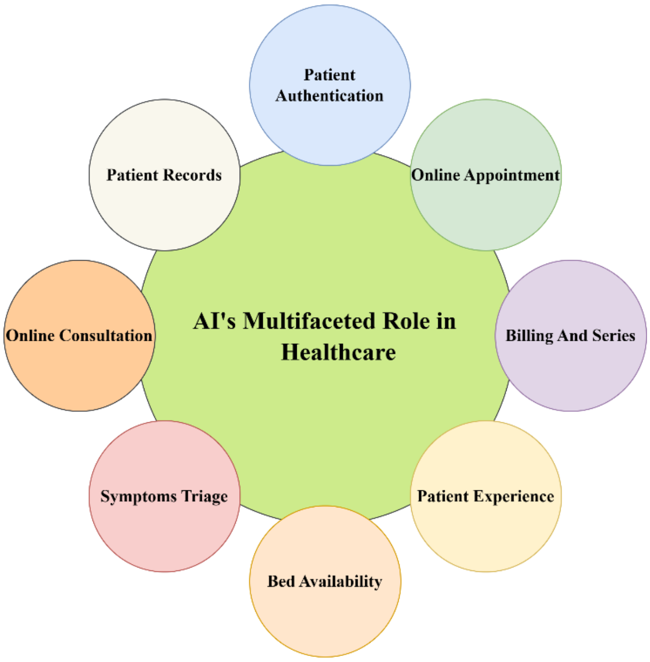

Figure 2. AI's impact on healthcare revolutionizing patient care and clinical decision-making.

Patient Experience: AI has transformed patient care by enabling personalized and tailored healthcare experiences. By investigating healthcare data and preferences, AI systems can anticipate patient needs and preferences, allowing healthcare providers to deliver customized care plans. Moreover, AI-driven patient navigation systems can guide patients through their healthcare journey, providing support and resources to ensure successful treatment outcomes. These AI-enabled solutions not only enhance patient fulfilment but also contribute to better-proven results and improved patient engagement [35].

Bed Availability: Efficient allocation of hospital resources, including bed availability, is essential for ensuring timely and effective patient care. AI technologies can portray an essential character in optimizing bed allocation by predicting patient outcomes and hospitalization needs[36]. By analyzing data from emergency department triage systems and other sources, AI algorithms can forecast patient admission rates and prioritize resource allocation accordingly. Incorporating this positive method not only elevates the calibre of patient care delivery but also intricately refines operational efficiency and optimizes resource allocation within healthcare facilities, thereby fostering a harmonious synergy in enhancing healthcare service provision [37].

Symptoms Triage: In the dynamic role-playing of public health crises like the COVID-19 pandemic, AI emerges as a stalwart sentinel, wielding its prowess to screen and triage patients with finesse. Delving into the depths of health data and symptoms, AI algorithms act as astute navigators, identifying those at the highest risk and orchestrating a symphony of healthcare interventions with precision and purpose. Moreover, AI-driven surveillance systems can monitor disease outbreaks and identify emerging trends, enabling healthcare authorities to respond effectively. These AI-enabled triage systems empower healthcare providers to allocate resources efficiently and mitigate the spread of infectious diseases [38].

Online Consultation: Telemedicine platforms powered by AI offer convenient and accessible healthcare services, enabling virtual consultations between patients and healthcare providers. These platforms leverage AI algorithms to analyze patient symptoms and medical history, facilitating accurate diagnosis and treatment recommendations. By eliminating geographical barriers and enabling remote care delivery, AI-driven telemedicine platforms broaden access to healthcare services and improve patient outcomes.

Patient Records: Electronic health record (EHR) systems powered by AI streamline the management of patient records, enhancing efficiency and accuracy in healthcare documentation. AI algorithms can automate data entry tasks, ensuring timely and accurate recording of patient information. Moreover, AI-enabled EHR systems can analyze medical data to identify patterns and trends, supporting clinical decision-making and care coordination. By improving the accessibility and interoperability of patient records, AI-driven EHR systems enhance the quality of healthcare delivery and patient safety[39].

3.3 Mathematical models in healthcare

Mathematical models are the compass guiding healthcare's transformation. They navigate the vast ocean of data, uncovering hidden patterns and charting a course towards better patient outcomes. Like sculptors transforming marble into masterpieces, these models meticulously analyze complex healthcare data, molding it into actionable insights. These insights inform decision-making, optimize processes, and drive innovation. Predictive models, with the precision of a surgeon's scalpel, forecast future events. This allows for proactive interventions that mitigate risk and personalize patient care. Mathematical models are the architects of efficiency, designing streamlined workflows and resource allocation strategies to enhance operational performance and reduce costs. In the ever-evolving landscape of healthcare, they stand as beacons of innovation, illuminating the path towards a future where every patient receives the tailored care they deserve. To harness the power of data in healthcare, mathematicians have developed powerful tools. In the realm of AI-driven healthcare, mathematical equations serve as the building blocks of innovation, empowering clinicians with data-driven insights and transforming the delivery of patient care. As AI continues to evolve, these equations stand as beacons of progress, guiding us towards a future where precision, personalized medicine, and improved outcomes are within reach for all.

Logistic Regression: AI in healthcare harnesses the predictive prowess of logistic regression to navigate the probability landscapes of medical outcomes. Like a skilled navigator, AI analyzes patient data to chart the likelihood of disease onset or treatment success, guiding clinicians towards informed decisions and personalized interventions. The mathematical equation of logistic regression model is given in equation (1).

$$P(Y=1)=\frac{1}{1+e^{-(\beta_0+\beta_1X_1+\beta_2X_2+\cdots+\beta_nX_n)}} \tag{1}$$

Here, LR calculates the probability of Y being 1 using predictor variables $(X_1, X_2, \ldots, X_n)$ and $coefficients(\beta_0, \beta_1, \beta_2, \ldots, \beta_n)$.

Linear Regression: With the precision of a surgical scalpel, AI applies linear regression to dissect the intricate relationships between patient variables and health outcomes. By drawing straight lines through clouds of data, AI predicts trends and patterns, empowering clinicians to anticipate disease progression and tailor treatment plans accordingly. The mathematical equation of the linear regression model is presented by equation (2).

$$Y=\beta_0+\beta_1X_1+\beta_2X_2+\cdots+\beta_nX_n+\epsilon \tag{2}$$

Where Y is the predicted outcome variable, $(X_1, X_2, \ldots, X_n)$ are the predictor variables, $(\beta_0, \beta_1, \ldots, \beta_n)$ are the coefficients, and ϵ represents the error term.

Neural Network activation function: Within the neural networks of AI-driven healthcare, activation functions like the sigmoid function act as gatekeepers of knowledge, shaping raw data into actionable insights. By bending inputs into outputs with graceful curves, AI perceives subtle patterns in medical data, uncovering hidden correlations and guiding diagnostic and therapeutic decisions. Equation (3) represents the sigmoid activation function as:

$$f(x)=\frac{1}{1+e^{-x}} \tag{3}$$

This function transforms the input x into a value between 0 and 1, making it suitable for binary classification tasks in neural networks.

Mean Squared Error (MSE): AI in healthcare adopts the mean squared error formula as a critical metric for assessing model accuracy and performance. Like a vigilant guardian, AI evaluates the gaps between predicted and actual outcomes, striving to minimize errors and optimize the precision of diagnostic and prognostic algorithms. The equation (4) presents the mathematical formula for Mean Squared Error (MSE):

$$\text{MSE} = \frac{1}{n}\sum_{i=1}^{n}\left(Y_i - \widehat{Y_i}\right)^2 \tag{4}$$

This formula calculates the average of the squared differences between predicted $\left(\widehat{Y_i}\right)$ and actual (Y_i) values, providing a measure of the model's accuracy in predicting continuous outcomes.

Risk Assessment using Bayesian inference: In the realm of medical diagnosis and risk assessment, AI employs Bayesian inference as a trusted ally, blending probability theory with clinical intuition to weigh the evidence of symptoms against the likelihood of disease. Through probabilistic reasoning, AI aids clinicians in making informed decisions and prioritizing patient care. The risk assessment formula utilizing Bayesian inference, denoted by equation (5), is:

$$P(Disease|Symptoms) = \frac{P(Symptoms|Disease) * P(Disease)}{P(Symptoms)} \tag{5}$$

Convolutional neural network (CNN) for image classification: With the artistry of a master painter, AI uses CNNs to analyze medical images and detect subtle signs of disease. By applying layers of convolution and classification, AI creates vivid portraits of pathology, enabling early detection and precise localization of abnormalities. The equation for image classification employing CNN is expressed mathematically in equation (6).

$$y = f(W * x + b) \tag{6}$$

Where, y as output, f as activation function, W as weights, x as input image, and b as bias term.

Recurrent neural network (RNN) for time series data analysis: Across the continuum of patient care, AI employs RNNs to analyze time-series data and forecast future health trends. Like a vigilant sentinel, AI captures temporal patterns in patient records, alerting clinicians to potential risks and opportunities for intervention. The RNN equation for time series data analysis is shown in equation (7), where h_t represents the hidden state at time t, x_t denotes the input at time t, W_{hx} and W_{hh} are weight matrices, b_h is the bias term, and tanh is the hyperbolic tangent activation function.

$$h_t = \tanh(W_{hx}x_t + W_{hh}h_{t-1} + b_h) \tag{7}$$

***Support vector machine (SVM) for classification*:** In the realm of medical classification, AI relies on SVMs to delineate boundaries between health states and disease states. By maximizing the margin of separation between classes, AI empowers clinicians to make confident diagnoses and treatment decisions. The equation for the SVM model for classification is provided in equation (8), where $f(x)$ represents the decision function, α_i and y_i are the Lagrange multipliers and corresponding class labels, $K(x_i, x)$ is the kernel function, and (b) is the bias term.

$$f(x) = \text{sign}\left(\sum_{i=1}^{N} \alpha_i y_i K(x_i, x) + b\right) \tag{8}$$

K-means clustering (KMC) Algorithm: Within the mosaic of patient populations, AI employs K-means clustering to identify cohorts of similar individuals. By partitioning patients into cohesive groups based on shared characteristics, AI facilitates personalized medicine and targeted interventions. The mathematical equation for the K-means clustering algorithm is presented in equation (9), where $C_i$represents the cluster centroids, x denotes the data points, and μ_i signifies the mean of the data points in cluster i .

$$\arg\min_C \sum_{i=1}^{k}\sum_{x\in C_i}||x - \mu_i||^2 \tag{9}$$

Bayesian network for probabilistic graphical models: Across the network of medical relationships, AI constructs Bayesian networks to model causal dependencies and predict outcomes. By threading nodes of causality and inference, AI enables clinicians to understand the complex interplay of factors influencing patient health and well-being. The mathematical equation for probabilistic graphical models is expressed in equation (10), where $P(X_1, X_2, \ldots, X_n)$ represents the joint probability distribution of variables X_1 through X_n, $and\ Parents(X_i)$ denotes the parent nodes of variable X_i in the graphical model.

$$P(X_1, X_2, \ldots, X_n) = \prod_{i=1}^{n} P\big(X_i \big| Parents(X_i)\big) \tag{10}$$

4 Ethical and privacy concern

Many believe AI will revolutionize the healthcare sector, affecting everything from workflow optimization in hospitals to scientific programs in imaging and diagnostics to the usage of fitness applications to evaluate symptoms and signs in fictional characters. The AI health industry is expected to develop significantly in the years to come, according to financial analysts. One estimate puts the market's growth at a multiple of 10 between 2014 and 2021. This development is accompanied by many challenges; thus, it is critical that AI be integrated into the healthcare system in a way that is compliant with the law and moral principles [40]. The IoT and AI have combined to provide a degree of technological innovation and development never seen before. Although there are many advantages to this technology, there are also major ethical concerns [41]. The combination of IoT with AI creates a network of networked devices and intelligent algorithms, which raises the possibility of ethical dilemmas involving privacy, security, bias, and responsibility, among other issues. The ethical dilemmas raised by the confluence of AI and IoT, as well as its societal implications, are examined in this article.

The fusion of IoT and AI technologies presents a paradigm-shifting potential to revolutionize entire industries and elevate global quality of life. However, this convergence also unveils a plethora of ethically nuanced scenarios. This article delves into the moral quandaries posed by artificial intelligence and the Internet of Things, encompassing issues of accountability, transparency, equity, privacy, and security. Through a critical evaluation of these complex situations, our aim is to offer insights into the conscientious design and responsible deployment of IoT and AI systems. Furthermore, we offer a graphic depiction of the complexities using a block diagram that emphasizes the crucial contributions and interactions in the context of IoT and AI [33], [38].

Figure *3* presents a pictorial view of the various types of ethical challenges intricately associated with the intersection of IoT and AI technologies.

4.1 Ethical challenges associated with IOT and AI

Privacy Concern: The primary issues are access to, use of, and management of personal data regarding affected persons. A few prior public-private partnerships with the goal of using AI have produced horrendous privacy security. Consequently, there was a need for more systematic oversight of extensive health records research. The privacy of patient employers should be safeguarded by appropriate security methods [42]. Private record keepers need structural support in order to protect confidential data and stop illegal use. They might be impacted by competing goals. The possibility of external privacy breaches using AI-powered methods is an additional cause for concern. Given that new algorithms have successfully located these sorts of information again, the ability to access or de-identify patient fitness data may be compromised or perhaps destroyed. The possibility of handling data under private custodianship may rise as a result [43], [44].

Vulnerabilities: AI has made every situation and thrill more exciting in a world where technology is advancing at an incredible rate. There are significant security and privacy problems arising from the increasing number of AI structures being incorporated into our daily life. Because AI can scan vast amounts of data and make judgments without human oversight, it poses a severe threat to our personal and social well-being[7], [45]. This prologue is an invitation to explore the many aspects of privacy and safety in AI as we go ahead into the uncharted waters of this rapidly expanding generation.

Bias in Data: We usually think of AI as an impartial entity that may help humans make wiser decisions. However, the reality is that AI, like its human designers, often displays bias. In the context of synthetic intelligence, bias is the input of erroneous or biased data that might produce false conclusions into information units, algorithms, or fashions [46]. Records bias can arise when the data used to train an AI system is not reflective of the real world. Algorithmic bias can occur when an AI system's algorithms aren't designed with honesty in mind.

Lack of Explainability: Not every component of artificial intelligence has been described as simply as one might think. Many of the AI methods that are now in use can be quite complex, if not entirely opaque. For instance, so-called "black field" models may grow too complicated even for professionals to completely understand, and complex statistical sample reputation algorithms may become too difficult to interpret [42].

Autonomy Vs Control: The concept of autonomy versus control encapsulates a pivotal distinction in the realm of AI deployment. Within various industries, the autonomy inherent in AI applications is highly esteemed, offering a versatile toolset for diverse tasks. These technologies possess the capability to operate independently or collaboratively, synergizing efforts towards desired outcomes. A succinct comparison underscores AI's primary focus on problem-solving, while autonomous robots excel in executing final tasks or refining assignments. AI-enabled autonomy, therefore, embodies machines, systems, or computer software's capacity to operate independently within predefined parameters, effectively navigating objectives or solving intricate problems. This autonomy, while granting freedom of action, remains bounded by predetermined constraints, ensuring alignment with overarching goals and the resolution of specific challenges [21], [47].

Transparency*:* If facts are the AI system's nourishment, then algorithms are the device's brain. AI systems rely on algorithms to make decisions or make predictions, particularly those that incorporate device learning. To reach the required degree of accuracy, these device-learning algorithms frequently get more intricate. Consequently, it becomes increasingly difficult for human viewers to comprehend them. Numerous machine learning methods, including deep learning, can also contain hundreds of variables and several tiers of processing, making the field opaque and a "black hole". It becomes everyone's duty to elucidate the approach and essential elements of a forecast or decision [48].

Figure 3. Ethical considerations and dilemmas arising from the integration of IoT and ai technologies in healthcare.

5 Personalized precision medicine

Consider going to the doctor when your health is deteriorating. Rather than treating you the same as everyone else with similar symptoms, the doctor takes into account your unique characteristics, including age, genetics, and lifestyle. They use all this information to design a unique treatment plan just for you. You expedite your recuperation by receiving the greatest, most customized treatment available in this way. Getting a highly customized healthcare plan is comparable to getting a precise medication. Using cutting-edge technology, scientists and medical professionals analyze your proteins, DNA, and other constituents. This facilitates their comprehension of exactly what is occurring to your body at a given moment. With this knowledge, they can decide on the best treatments and options for you that will most likely result in the results you want. It all boils down to giving you the appropriate care at the appropriate time while enhancing the precision and efficacy of medical care. Instead of taking a one-size-fits-all stance, our goal is to find ways to customize therapies to the distinct clinical and lifestyle traits of each individual. AI-powered tailored medicine may make it possible to treat uncommon diseases like cystic fibrosis as well as common ones like heart disease and the majority of cancers more effectively [41]. AI methods are used in precision medicine to discover novel genotypes and phenotypic data. Precision medicine aims to diagnose patients early, screen them, and provide a specified medication plan related to the patient's genetically determined functions and attributes. Large volumes of genetic knowledge are included in the incredibly complicated genomic data. In order to find genetic variations and mutations, AI systems are very adept at swiftly and precisely evaluating and interpreting this data. By comparing a patient's genetic data with a vast library of genetic data from different patients, AI is able to analyze the patient's genetic data. This enables the identification of certain genetic markers or variants that might affect an individual's response to therapies, susceptibility to illnesses, or risk factors [49]. Devices with AI capabilities enable physicians to prescribe more precisely customized pharmaceuticals based on each patient's genetic composition, a practice known as personalized medicine. This strategy holds the promise of enhancing patient outcomes, mitigating adverse effects, and optimizing the allocation of healthcare resources. The study as a whole examines how AI and its suite of tools can facilitate the discovery of optimal pharmaceutical treatments for individual patients, thereby streamlining processes, conserving time, and enabling the delivery of tailored therapy.

5.1 Disease identification using AI

Table 2. Overview of AI and IoT applications in genomic analysis and patient care.

Application	Description	Category	Use of AI and IoT
Data processing and interpretation	AI systems quickly and accurately process and interpret complex genomic data to identify genetic alterations and mutations.	Genomic data analysis	AI in healthcare, Genomic data analysis
Personalized medicine	AI compares a patient's genetic data with a database to identify specific genetic markers or mutations affecting risk factors, response to therapies, or disease susceptibility.	Precision medicine	AI in healthcare, Personalized medicine
Predictive analytics	Machine learning algorithms in AI predict a patient's future health risks based on their genetic makeup, assessing the likelihood of developing diseases like diabetes, heart disease, or cancer.	Risk prediction	AI in healthcare, Predictive analytics
Treatment recommendations	AI suggests individualized treatment based on a patient's genetic profile, identifying effective treatments and potential side effects.	Treatment planning	AI in healthcare, Treatment recommendation
Drug discovery	AI uses genomic data to identify potential drug targets, expediting the development of customized therapies.	Drug development	AI in healthcare, Drug discovery
Real-time monitoring	AI continuously monitors a patient's genetic information and overall health, dynamically adjusting treatment plans and providing early warning signs of health issues.	Continuous health monitoring	AI in healthcare, Real-time monitoring
Healthcare cost reduction	AI personalizes treatment, reducing the use of ineffective medicines and lowering healthcare costs.	Cost-effective healthcare	AI in healthcare, Healthcare cost reduction
Privacy and security	AI systems prioritize patient data privacy and security, safeguarding sensitive genetic information.	Data privacy protection	AI in healthcare, Privacy and security

Table 2 encapsulates a comprehensive analysis of how AI revolutionizes disease identification across various facets of healthcare. Firstly, AI's proficiency in data processing and interpretation is paramount, particularly in genomics, where it swiftly and accurately analyzes intricate genetic data to uncover critical insights, such as genetic alterations and mutations. This capability significantly advances genomic data analysis in healthcare, facilitating more precise diagnostics and personalized treatment strategies tailored to individual genetic profiles. Moreover, AI drives personalized medicine by leveraging vast databases to compare patients' genetic data, identifying specific genetic markers influencing disease susceptibility, treatment responses, and risk factors. Predictive analytics, fueled by AI-driven machine learning algorithms, enables the anticipation of patients' future health risks based on their genetic makeup, empowering healthcare providers to proactively address potential health concerns and mitigate disease progression [40]. Additionally, AI plays a pivotal role in treatment recommendations by utilizing individual genetic profiles to formulate tailored treatment plans, optimizing therapy effectiveness while minimizing adverse effects. In drug discovery, AI harnesses genomic data to identify promising drug targets, expediting the development of targeted therapies and enhancing treatment outcomes. Real-time monitoring, facilitated by AI, continuously tracks patients' genetic information and health status, enabling dynamic treatment adjustments and early detection of emerging health issues. This real-time surveillance capability enhances patient care delivery and contributes to better health outcomes [50]. Furthermore, AI contributes to healthcare cost reduction by personalizing treatment regimens, optimizing resource allocation, and mitigating the use of ineffective medications. By tailoring treatments to individual patient needs and leveraging predictive analytics, AI helps healthcare systems streamline operations and allocate resources more efficiently, ultimately reducing overall healthcare costs. Finally, AI prioritizes patient data privacy and security, implementing robust measures to safeguard sensitive genetic information and ensure compliance with privacy regulations. This commitment to data privacy protection underscores the ethical and responsible deployment of AI technologies in healthcare, fostering trust and confidence among patients and stakeholders alike.

5.2 AI Tools in healthcare

Table 3. Overview of AI tools in healthcare, covering applications, descriptions, ML/DL models, and data types.

AI Tools in Healthcare	Description	Application	ML/DL Models	Types of Data
Genomic analysis platform	AI-powered systems analyze patient genomic data to identify genetic variants and mutations, offering insights into genetic predispositions and predicting responses to new medications.	Genomic analysis, Precision medicine	CNN, RNN, SVM, Random Forest	Genomic sequencing data
Treatment recommendations	AI algorithms personalize treatment options based on a patient's genetic profile, considering unique genetic markers to suggest therapies with the highest efficacy.	Precision medicine, Treatment recommendation	ANN, Decision Trees, Random Forest	Genetic data
Clinical decision support system (CDSS)	AI-driven CDSS integrates genetic data with medical records to provide real-time advice on dosages, alternative therapies, and genetic-medicine correlations.	Clinical decision support, Precision medicine	CNN, LSTM, Decision Trees, SVM	Genetic data, medical records
Predictive modelling	AI constructs prediction models to assess a patient's current genetic risk of developing specific illnesses, facilitating early detection and preventive interventions.	Predictive analytics, Early disease detection	Logistic Regression, Gradient Boosting	Genetic data
Pharmacogenomics	AI analyzes genetic data to predict how a patient's genetic makeup influences their response to existing medications, aiding prescribers in selecting drugs with optimal effectiveness.	Pharmacogenomics, Precision medicine	SVM, Decision Trees, Random Forest	Genetic data, Drug response data
Information integration systems	AI systems integrate patient genetic data with medical history, electronic health records, and test results, enabling informed treatment decisions.	Precision medicine, Clinical decision support	ANN, LSTM, Decision Trees, SVM	Genetic data, electronic health records
Treatment monitoring	AI continuously monitors patient responses to new medications by analyzing genetic data, alerting healthcare providers to changes in medication effectiveness or adverse reactions.	Treatment monitoring, Precision medicine	CNN, RNN, LSTM, Decision Trees	Genetic data, Patient monitoring data

Table 3 provides a comprehensive overview of various AI tools deployed in healthcare settings, each designed to harness patient genetic data for improved medical decision-making and personalized treatment approaches. The Genomic Analysis Platform stands out for its ability to delve into the intricate details of patient genomic data, identifying genetic variations and mutations that could hold crucial insights into individual health profiles. By employing advanced ML/DL models like CNN, RNN, SVM, and Random Forest, this tool enables precise genomic analysis and aids in the field of precision medicine, where treatment strategies are tailored to individual genetic profiles. This platform primarily operates on genomic sequencing data, extracting valuable information that could guide clinicians in making informed decisions regarding patient care[7], [34]. Similarly, the Treatment Recommendations tool capitalizes on patient genetic data to personalize treatment options, considering unique genetic markers and variations. By leveraging AI algorithms such as ANN, Decision Trees, and Random Forest, this tool sifts through genetic data to identify therapies with the highest likelihood of efficacy. With precision medicine as its primary application, this tool holds promise in revolutionizing treatment approaches by moving away from one-size-fits-all solutions towards individualized patient care[3], [5].

The Clinical Decision Support System (CDSS) is another indispensable AI tool that seamlessly integrates genetic data with medical records to provide real-time insights and recommendations. This dynamic system harnesses ML/DL models like CNN, LSTM, Decision Trees, and SVM to analyze genetic and medical record data, empowering clinicians with actionable insights for treatment planning and decision-making. From dosing recommendations to alternative therapy suggestions, CDSS bridges the gap between genetic insights and clinical practice, enhancing precision medicine initiatives[24]. Predictive Modelling, on the other hand, focuses on forecasting a patient's future health risks based on their genetic makeup. By utilizing ML algorithms such as Logistic Regression and Gradient Boosting on genetic data, this tool enables early disease detection and preventive interventions. Pharmacogenomics, another vital application, delves into the realm of how a patient's genetic makeup influences their response to medications. With ML models like SVM, Decision Trees, and Random Forest, this tool aids prescribers in selecting drugs with optimal effectiveness, thereby optimizing treatment outcomes. Information Integration Systems serve as the backbone of healthcare data management, seamlessly integrating patient genetic data with electronic health records and medical history. By employing AI models like ANN, LSTM, Decision Trees, and SVM on genetic and electronic health record data, this tool facilitates informed treatment decisions and enhances clinical decision support. Lastly, Treatment Monitoring employs a range of ML/DL models like CNN, RNN, LSTM, and Decision Trees to continuously monitor patient responses to medications. By analyzing genetic and patient monitoring data, this tool ensures timely intervention and adjustments to treatment plans, ultimately improving patient outcomes in precision medicine settings[41].

5.3 Global trends in healthcare IoT

Figure 4 presents a comprehensive depiction of the adoption and expansion of healthcare IoT connections across various regions worldwide from 2018 to 2028 [51]. The figure compares the number of healthcare IoT devices (in millions) across four major continents: Asia, Africa, America, and Europe. It is evident from the figure that the global growth of IoT in healthcare surpasses that of the individual continents, with Asia exhibiting the highest growth rate among them all. Global Trend and Growth Rate: The depicted data portrays a substantial surge in the volume of healthcare IoT connections globally over the specified ten-year period. Beginning at 197.60 million connections in 2018, the figures steadily climb, reaching a substantial milestone of 2,766.00 million connections by 2028. This trend underscores a notable growth rate in the implementation of IoT tools within the healthcare area, emphasizing its increasing significance in modern healthcare delivery and management practices. This upward trajectory signals a paradigm shift in healthcare, with IoT playing a pivotal role in revolutionizing patient care, treatment efficacy, and healthcare infrastructure management on a global scale[2], [51]. Regional Disparities and Trends: The data reveals significant regional variations in the deployment of healthcare IoT connections, with Asia consistently leading in the number of connections, followed by the Americas, Europe, and Africa. Asia's trajectory reflects robust growth, starting from 56.34 million connections in 2018 and steadily increasing to an impressive 837.60 million connections by 2028. In contrast, Africa, with the lowest initial count of 26.55 million connections in 2018, has shown steady progress over the years. The Americas and Europe also demonstrate substantial growth, indicating a widespread adoption of IoT technology in healthcare across these regions. These disparities underscore the diverse pace and extent of IoT integration within healthcare systems worldwide, influenced by factors such as technological infrastructure, healthcare expenditure, and regulatory environments. Addressing these regional differences is crucial for ensuring equitable access to innovative healthcare technologies. Collaboration among stakeholders, including healthcare institutions, governments, technology creators, and international organizations, is vital to foster inclusive IoT adoption and maximize its potential benefits for healthcare delivery and patient outcomes globally[51].

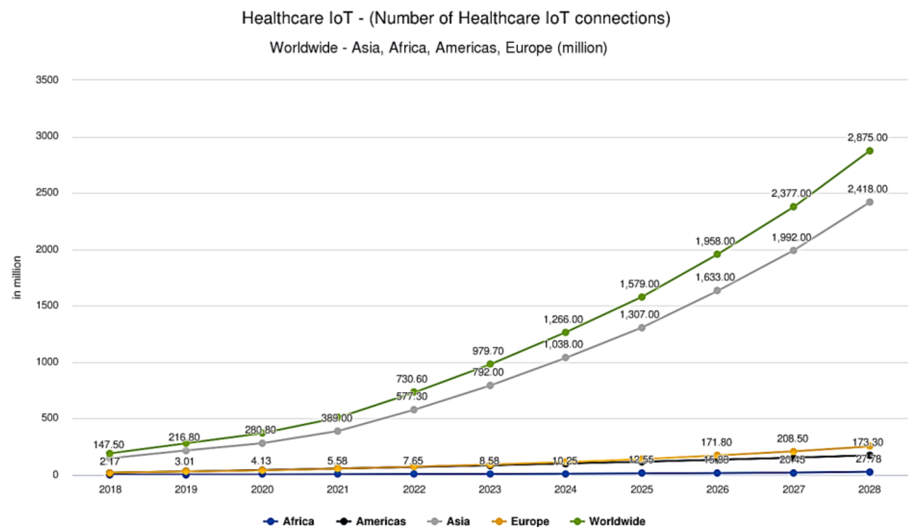

Figure 4. Global adoption and proliferation of healthcare IoT connections, 2018-2028 [51].

Factors Driving Growth: The burgeoning adoption of IoT tools in the healthcare area can be ascribed to a multitude of factors, elucidated by the data. These encompass the evolution of sensor technology, which enables the seamless integration of IoT devices into medical equipment and infrastructure, thereby enhancing data collection and analysis capabilities. Furthermore, the escalating prevalence of chronic ailments necessitates continuous monitoring and personalized care, fostering the demand for remote patient monitoring solutions facilitated by IoT connectivity. Moreover, the imperative for more streamlined and data-centric healthcare delivery systems underscores the significance of IoT in optimizing resource allocation, patient care pathways, and treatment outcomes. Additionally, the advent of telemedicine platforms, which leverage IoT to enable virtual consultations and remote diagnostics, contributes significantly to the proliferation of IoT connections in healthcare settings. Furthermore, the incorporation of IoT devices into wearable technology for real-time health monitoring offers unparalleled insights into patient health metrics, driving further adoption. Lastly, the emphasis on predictive analytics and data-driven executives in healthcare management underscores the role of IoT in facilitating proactive interventions and preventive care strategies, ultimately driving the expansion of IoT connections in the healthcare landscape.

Implications and Opportunities: The surge in healthcare IoT connections heralds a transformative shift in healthcare delivery paradigms, promising advancements in patient care quality, operational efficiency optimization, and resource allocation efficacy across healthcare institutions. This trend unveils a plethora of opportunities for innovation, encompassing the creation of remote patient monitoring solutions, telemedicine services, intelligent healthcare infrastructure, and data analytics platforms tailored for informed healthcare decision-making. Furthermore, the escalating integration of IoT technology in healthcare holds immense prospective to transform conventional healthcare models, covering the approach for personalized and proactive approaches to patient care. Moreover, it presents a means to address longstanding challenges pertaining to healthcare accessibility, affordability, and quality, thereby steering in a new period of healthcare innovation and excellence. Figure 5 depicts the current state and predicted future of AI adoption in healthcare. The graph shows the percentage of healthcare institutions currently utilizing AI technologies (* indicates projected values). It reveals a gradual but steady increase in AI adoption across various healthcare sectors over time. This trend underscores the growing importance of AI as it integrates more deeply into medical practices and systems. The predicted values, furthermore, offer a glimpse into the anticipated trajectory of AI adoption.

These predictions suggest significant advancements and transformations in healthcare delivery, driven by the power of AI innovation.

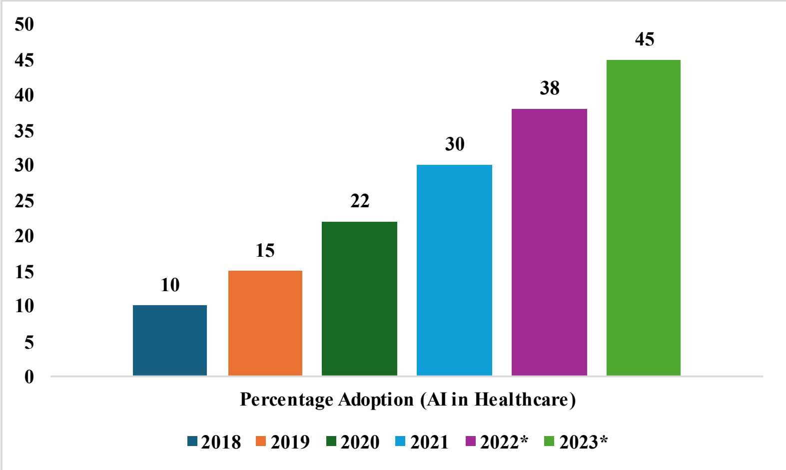

Figure 5. The percentage growth of AI adoption in healthcare [47].

Figure 6 presents the global revenue statistics, measured in billions of USD (US$), of top healthcare companies worldwide and their consolidated financial data from 2018 to 2022. The revenue figures encapsulate the financial performance of key industry players, including Abbott Laboratories, Boston Scientific, Koninklijke Philips, and Medtronic, over the specified time frame. From 2018 to 2022, Abbott Laboratories witnessed steady growth, with revenue climbing from 30.58 billion USD in 2018 to 43.65 billion USD in 2022. Similarly, Boston Scientific experienced an upward trend, with revenue increasing from 9.82 billion USD in 2018 to 12.68 billion USD in 2022. On the other hand, Koninklijke Philips demonstrated a fluctuating revenue trend, reaching 21.41 billion USD in 2018 and stabilizing around 19.94 billion USD by 2022. Medtronic's revenue trajectory fluctuated over the years, peaking at 30.56 billion USD in 2018 and reaching 31.69 billion USD in 2021.

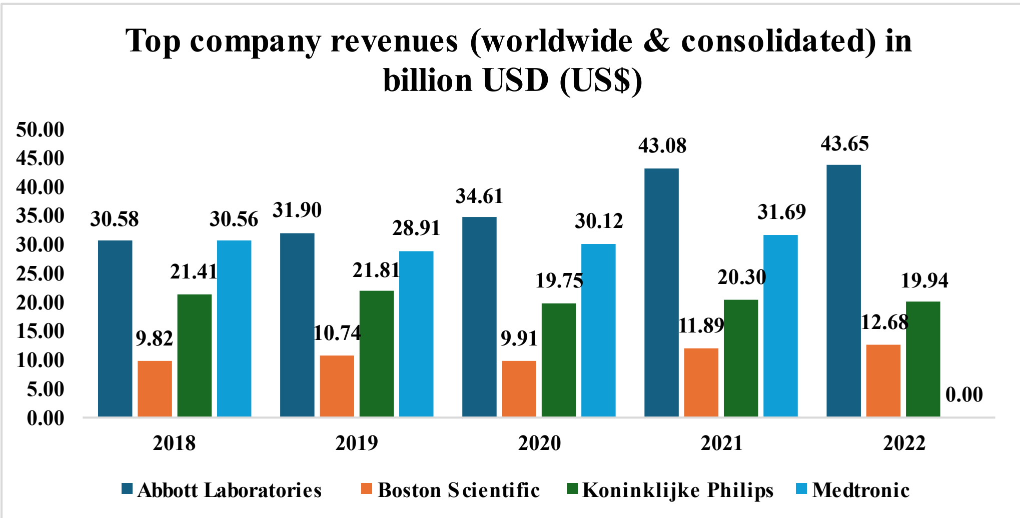

Figure 6. Global revenue of leading companies (Billions of USD) [51].

6 Conclusion

In this study, we provided an exhaustive review of the way AI and the IoT are transforming the healthcare industry. Our findings demonstrate that AI improves diagnosis precision and customized medications, making it an effective supporting tool for medical professionals. IoT incorporates a variety of smart medical devices, including heart monitors, wearable health tracking devices, and modern clinical systems, allowing for seamless data interchange and enhancing patient management. These smart devices offer real-time health monitoring, timely interventions, and better outcomes, while also automating regular operations such as appointment scheduling and handling inventories. Despite these developments, we have identified serious ethical and privacy concerns about AI and IoT technology. While the benefits are significant, including improved utilization of resources and individualized care based on genetic profiles, concerns about the privacy of patients and integrity must be addressed. In the context of the future scope, the integration of IoT and AI promises more improvements in healthcare. To further expedite data integration and enhance patient outcomes, future research endeavours must concentrate on augmenting the compatibility of smart devices and AI systems. Strong frameworks are also required to handle privacy and ethical concerns, ensuring that technology improvements are applied properly. It will be essential to investigate novel AI algorithms for more precise diagnosis and create innovative IoT applications for preventative health care. In order to ensure that the benefits of new technologies are experienced by a larger population, continued efforts should also focus on making them equitable and accessible.

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